Response Under 37 CFR 1.116
Expedited Procedure
Examining Group 2873

Remarks

Headings of this AAFA correspond to the headings of the AAFA.

Specification

The title of this application is changed as follows:

Projection ~~Objection~~ Objective for Microlithography

A substitute specification without the claims (pages 17-21) filed under 37 CFR1.125(a) is submitted herewith. The substitute specification contains only subject matter from the original specification.

Claim Rejections under 35 USC 102(b)

Claims 5, 6, 10 and 22 are rejected as anticipated by Sasaya et al. (Sasaya) or Yamaguchi et al (Yamaguchi) or Araki.

DE 198 18 444 A1 is also US 6,008,884.

Claims 5, 6 and 10 are cancelled.

Claim 8 is amended by explicitly entering former claims 5 and 6.

Claim 22 is cancelled.

Claims 23 and 24 take the wording from claim 22 and the values of claims 23 and 24.

A Terminal Disclaimer concerning pending application 09/847,658, filed May 2, 2001, is submitted herewith.

Wherefore, further consideration and allowance of the claims is respectfully requested.

A three-month extension of time in which to respond to the outstanding Office Action is hereby requested. A PTO-2038 authorizing credit card payment for the amount of $950 is enclosed for the prescribed Large Entity three-month extension fee, $110 for the terminal disclaimer fee and $330 for the Notice of Appeal fee. Any other fees due by virtue of this filing or this application should be charged to Deposit Account 11-0665. Any refunds in connection with this filing should be credited to Deposit Account 11-0665. A duplicate of this page is enclosed for this purpose.

Respectfully submitted,

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I hereby certify this correspondence is being submitted to Commissioner for Patents, Alexandria, VA, 22313 by facsimile transmission on March 30, 2004p, fax number (703) 872-9306.

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Projection ~~Objection~~ Objective for Micr lith graphy

Cross References to Related Applications

This application is a continuation application of PCT/EP99/10233, which is pending. German Applications DE 198 55 108A, DE 198 55 157A, and DE 198 55 158A, in which the Applicant participated, are incorporated herein by reference.

Statement Regarding Federal Sponsored Research or Development – Not Applicable.

Reference to a Microfiche Appendix – Not Applicable.

Background of the Invention

Technical Field

The invention relates to a projection objective with a lens arrangement, which can be divided into six lens groups. The first, third, fifth and sixth lens groups have positive power and the second and fourth lens groups respectively have negative power. The division of the lens system into lens groups is described in more detail hereinafter, based on the direction of propagation of the radiation.

The first lens group is positive and ends with a lens of positive power. A bulge is formed by the first lens group; it is unimportant if negative lenses are also arranged in the bulge.

The second lens group is of negative total power. This second lens group has as its first lens a lens having a concave lens surface toward the image. This second lens group substantially describes a waist. Here, also it is not of substantial importance if a few positive lenses are included in the second lens group, as long as the waist is maintained.

The third lens group begins with a lens having positive power and a convex lens surface on the image side, and which can be a meniscus. If a thick meniscus lens is provided as the first lens, the separation of the lens groups can be considered to be within the lens.

The fourth lens group is of negative power. This fourth lens group begins with a lens of negative power, followed by several lenses having negative power. A waist is formed by this lens group. It is unimportant if lenses having positive power are also contained within this lens group, as long as these influence the course of the beam over only a short distance and thus the waisted shape of the fourth lens group is maintained.

The fifth lens group has positive power overall. The first lens of this fifth lens group has a convex lens surface on the image side. A bulge is formed by the fifth lens group.

After the lens of maximum diameter (the bulge), there follow at least an additional two positive lenses in the fifth lens group, further negative lenses also being permitted.

The sixth lens group is likewise positive in its total power. The first lens of the sixth lens group is negative and has on the image side a concave lens surface. This first lens of the sixth lens group has a considerably smaller diameter in comparison with the maximum diameter of the bulge.

Background Art

Such projection objectives are in particular used in microlithography. They are known, for example, from the German Applications DE 198 55 108A, DE 198 55 157A, and DE 198 55 158A, in which the Applicant participated, and from the state of the art cited therein. These documents are incorporated herein by reference.

These projection objectives are usually constructed from purely spherical lenses, since the production and testing technology is advantageous for spheres.

Projection objectives are known from German Application DE 198 18 444 A1 which have lenses having aspheric surfaces in at least the fourth or fifth lens group. An increase of the numerical aperture and of the image quality can be attained by means of the aspheric surfaces. The projection objectives shown have a length from the mask plane to the image plane of 1,200 mm to 1,500 mm. A considerable use of material is associated with this length. High production costs are entailed by this use of material, since because of the required high image quality only high quality materials can be used. Aspheric lenses up to a diameter of about 300-mm are required, the provision of which is particularly expensive. It is not at all clear in the technical world whether aspheric lenses with such large lens diameters can be provided in the required quality. "Aspheric surfaces" are understood to include all surfaces which are not spherical and which are rotationally symmetrical. Rotationally symmetrical splines can also be considered as aspheric lens surfaces.

Summary of the Invention

The invention has as its object to provide a projection objective which has as few lenses as possible, with reduced use of material, the aspheric lens surfaces used being as few and as small as possible, with the lowest possible asphericity. A high aperture projection objective of short structure is to be cost-efficiently provided in this way.

The object of the invention is attained in particular by a projection objective for microlithography having a lens arrangement comprising a first lens group having positive power;

a second lens group having negative power; a third lens group having positive power; a fourth lens group having negative power; a fifth lens group having positive power; and a sixth lens group having positive power; wherein a lens at the end of the second lens group, particularly the last lens of the second lens group, or a lens at the beginning of the third lens group, particularly the first lens of the third lens group, has an aspheric surface. In addition, the object of the invention is attained by a projection objective having a lens arrangement having at least a first waist of a pencil of rays, wherein the lens arrangement comprises at least one of the following: a lens having an aspheric surface arranged before the first waist, a lens having an aspheric surface arranged after the first waist, and lenses having aspheric surfaces arranged before and after the first waist.

In a projection objective with a lens arrangement, by the measure of providing, in the forward half of this lens arrangement, at least one lens provided with an aspheric lens surface, the possibility was realized of furnishing a projection objective of compact construction and having a high image quality.

In the division of this lens arrangement into six lens groups: a first lens group having a positive power, a second lens group a negative power, a third lens group a positive power, a fourth lens group a negative power, and a fifth and sixth lens group respectively a positive power, a preferred position of the aspheric surface is at the end of the second lens group. It is then arranged, in particular, on the last lens of the second lens group or at the beginning of the third lens group, and indeed preferably on the first lens of the third lens group. A correction of image errors in the region between the image field zone and the image field edge is possible by means

of this aspheric lens surface. In particular, the image errors of higher order, which become evident on considering sagittal sections can be corrected. Since these image errors apparent in sagittal section are particularly difficult to correct, this is a particularly valuable contribution. In an advantageous embodiment, only one lens has an aspheric surface. This has a positive effect on the production costs, since it is the production of highly accurate aspheric surfaces that requires considerable technological effort, which entails increased costs. It was only with the use of exactly one aspheric lens that it was possible to provide a very compact objective, in which case the additional costs for the aspheric lens are not important, since considerable cost savings were connected with the reduction of the required material and of the surfaces to be processed and tested.

By the measure of providing a lens arrangement that has at least a first waist, an aspheric surface before and an aspheric surface after the waist, a lens arrangement is produced which makes possible a high numerical aperture with high image quality, particularly for the DUV region. In particular, it is possible by the use of these aspheric surfaces to furnish a projection objective of short structure and high image quality. Objectives used in microlithography generally have a high material density over their whole length, so that the reduction of the length is connected with a considerable saving of material. Since only very high-grade materials can be used for projection objectives, particularly for microlithography, the required use of material has a severe effect on the production costs.

The aspheric surface arranged before the first waist can be arranged at the end of the first lens group or at the beginning of the second lens group. Furthermore, it has been found to be

advantageous to arrange an aspheric surface, arranged after the first waist, on the last lens of the second lens group or on the first lens of the third lens group.

The aspheric surface provided before the first waist in particular makes possible a targeted correction of coma in the region of the image field zone. This aspheric lens surface has only a slight effect on the skew spherical aberration in tangential section and in sagittal section. In contrast to this, the skew sagittal aberration, particularly in the region between the image field zone and image field edge, can be corrected by the aspheric lens surface after the waist.

The provision of a second aspheric lens surface is thus a worthwhile measure, in order to counter at high numerical aperture a reduction of image quality due to coma.

In a few cases of application, particularly with very high numerical aperture, it has been found to be favorable to provide a projection objective wherein the third lens group has a lens having an aspheric surface, and, in particular, the last lens of the third lens group has an aspheric surface.

It has been found to be advantageous to provide a first lens in the sixth lens group with an aspheric surface for a further correction of coma, especially in the region of the image field edge. For this aspheric lens surface, the first lens of the sixth lens group has been found to be a particularly well suited position.

Furthermore, the numerical aperture can be increased, at constant image quality, by the provision of a further aspheric surface on the last lens of the third lens group.

It is an advantage of the invention to provide a refractive microlithographic projection objective, wherein all aspheric lens surfaces have a vertex radius (R) of at least 300-mm. Thus

the aspheric surfaces are provided on long radii, since the production and testing is easier for lens surfaces with long radii. These surfaces are easily accessible to processing equipment because of their low curvature. In particular, surfaces with long radii are accessible with Cartesian coordinates for tactile measurement processes.

It has been found to be advantageous to use at least two different materials for achromatization, for projection objectives designed for an illumination wavelength of less than 200 nm, because of the stronger dispersion of the lenses, even with the use of narrow-band light sources. In particular, fluorides, especially CaF_2, are known as suitable materials, besides quartz glass.

It has been found to be advantageous to provide at least two lenses of CaF_2, which are arranged before an aperture stop in the fifth lens group, for the correction of color transverse errors.

It has been found to be advantageous for the further correction of color errors to integrate an achromat after the aperture stop by means of a positive CaF_2 lens and a following negative quartz lens. This arrangement has a favorable effect on the correction of the spherical portions. In particular, longitudinal color errors can be corrected by the lenses after the aperture stop.

A reduction of the longitudinal error already results in general from the shortening of the length of the projection objective. Thus a good achromatization with a reduced use of CaF_2 lenses can be attained with the objective according to the invention.

Brief Description of the Drawings

The invention is described in more detail hereinafter with the aid of preferred

embodiments, in which:

Fig. 1 shows a schematic illustration of a projection exposure device;

Fig. 2 shows a lens section through a first lens arrangement of a projection objective with an aspheric lens surface;

Fig. 3 shows a lens section through a second lens arrangement, which has two aspheric lens surfaces;

Fig. 4 shows a lens section through a third lens arrangement, which has three aspheric lens surfaces;

Figs. 5a-5g illustrate tangential transverse aberrations;

Figs. 6a-6g illustrate sagittal transverse aberrations;

Figs. 7a-7f illustrate groove errors of the third lens arrangement with the aid of sections;

Fig. 8 shows a lens section through a fourth lens arrangement, which has three aspheric surfaces;

Fig. 9 shows a lens section through a fifth lens arrangement, which has four aspheric surfaces;

Fig. 10 shows a lens section through a sixth lens arrangement, which has four aspheric surfaces.

Detailed Description of Preferred Embodiments

The principle of the construction of a projection exposure device is first described with the aid of Fig. 1. The projection exposure device 1 has an illuminating device 3 and a projection objective 5. The projection objective includes a lens arrangement 19 with an aperture stop AP, an optical axis 7 being defined by the lens arrangement 19. A mask 9 is arranged between the illuminating device 3 and the projection objective 5, and is supported in the beam path by means

of a mask holder 11. Such masks 9 used in microlithography have a micrometer to nanometer structure, which is reduced by means of the projection objective 5 by a factor of up to 10, particularly a factor of four, and is imaged on an image plane 13. A substrate positioned by a substrate holder 17 or a wafer 15 is supported in the image plane 13. The minimum structures which are still resolvable depend on the wavelength λ of the light used for illumination, and also on the numerical aperture of the projection objective 5, the maximum attainable resolution of the projection exposure device 1 increasing with decreasing wavelength of the illuminating device 3 and with increasing numerical aperture of the projection objective 5.

The projection objective 5 contains, according to the invention, at least one aspheric surface to provide a high resolution.

Various embodiments of lens arrangements 19 are shown in Figs. 2-4 and 8-10.

These projection objectives 5 designed for more stringent requirements for image quality and for resolution, and in particular their lens arrangement 19, are described in more detail hereinafter. The data of the individual lenses L101-130, L201-230, L301-330, L401-429, L501-529, L601-629, can be found in detail in the associated tables. All the lens arrangements 19 have at least one aspheric lens surface 27.

These aspheric surfaces are described by the equation:

$$P(h) = \frac{\delta \bullet h \bullet h}{1+\sqrt{1-(1-EX)\bullet\delta\bullet\delta\bullet h\bullet h}} + C_1 h^4 + \ldots + C_n h^{2n+2} \qquad \delta = 1/R$$

in which P is the arrow height as a function of the radius h (height to the optical axis 7) with the aspheric constants C_1 through C_n given in the Tables. R is the vertex angle given in the Tables.

The lens arrangement 19 shown in Fig. 2 has 29 lenses L101-L129 and a plane parallel plate L-130. This lens arrangement 19 can be divided into six lens groups, which are denoted by LG1 for the first lens group through LG6 for the sixth lens group. The first, fifth and sixth lens groups have positive refractive power, while the second lens group LG2 and the fourth lens group LG4, by which a first waist 23 and a second waist 25 are formed, have negative refractive power. This lens arrangement 19 is designed for the wavelength λ = 193.3 nm which is produced by a KrF excimer laser, and has an aspheric lens surface 27. A structure width of 0.10 μm is resolvable with this lens arrangement 19 at a numerical aperture of 0.75. On the object side, the light transmitted by the lens arrangement propagates in the form of a spherical wavefront. In the objective, the greatest deviation from the ideal wavefront, also denoted by the RMS factor, is 10.4 mλ with respect to the wavelength λ = 193.3 nm. The image field diagonal is 28 mm. The constructional length from mask plane to object plane is only 1,000 mm, and the maximum diameter of a lens is 235 mm.

In this embodiment, this aspheric lens surface 27 is arranged on the side of the lens L110 remote from the illumination device.

The projection objective having the previously mentioned good performance data could

for the first time be furnished with the use of this aspheric lens surface 27. This aspheric lens surface 27 serves to correct image errors and also to reduce the required constructional length, with image quality remaining constant. In particular, image errors of higher order in the region between the image zone and image field edge are corrected here by this aspheric surface 27. This correction brings about, in particular, an increase in the image quality in the sagittal direction.

The dispersion of the available lens materials increases with shorter wavelengths. Consequently, increased chromatic image errors arise in projection objectives for short wavelengths such as 193 nm or 157 nm. The usual embodiment for 193 nm therefore has quartz glass as the flint and CaF_2 as the crown, as lens materials for achromatization.

With an overall minimum use of the problematic CaF_2, care has to be taken in that a CaF_2 lens L114 in the third lens group LG3 places an increased requirement on the homogeneity of the material, since it is arranged far from the aperture stop AP. For this purpose, however, it has a moderate diameter, which substantially improves the availability of CaF_2 with an increased requirement.

For the correction of color transverse error, three CaF_2 lenses L119, L120, L121 are arranged in the fifth lens group LG5, before the aperture stop AP. An achromat 37, consisting of a convex CaF_2 lens L122 and a following meniscus lens L123 of quartz glass are arranged directly behind the aperture stop AP. These CaF_2 lenses can be of lower quality than the CaF_2 lens L114, since quality deviations in the middle region can easily be simultaneously corrected for all image field regions (by lens rotation during adjustment).

A further CaF_2 lens L129 is arranged in the sixth lens group. It is possible by means of

this lens of CaF_2 to reduce the effects of lens heating and refractive index changes due to irradiation, named compaction.

The individual data for the lenses L101-L130 can be found in Table 1. The optically utilized diameter of all the CaF_2 lenses is less than 235 mm. Since the availability of CaF_2 is furthermore limited in dependence on the diameter required, the required diameter of the CaF_2 lenses used is of central importance.

A lens arrangement 19 designed for the wavelength $\lambda = 248$ nm is shown in section in Fig. 3. This lens arrangement 19 has two aspheric lens surfaces 27, 29. The first aspheric lens surface 27 is arranged on the image side on the lens L210. It can also be provided to arrange this second aspheric lens surface 27 on the side of the lens L211 facing toward the illumination device. The two lenses L210 and L211 are predetermined for the reception of the aspheric lens surface 27. Provision can also be made to provide a meniscus lens having an aspheric lens surface instead of the lenses L210 and L211. The second aspheric lens surface 29 is arranged in the end region of the first lens group, on the side of the lens L205 remote from the illumination device 3. It can also be provided to arrange this aspheric lens surface 29 on the lens L206 following thereafter in the beginning of the second lens group.

A particularly great effect is obtained when the aspherics 27, 29 are arranged on lens surfaces at which the incident rays include a large angle with the respective surface normals. In this case the large variation of the angle of incidence is important. In Fig. 10, the value of sin i at the aspheric lens surface 31 reaches a value of up to 0.82. Because of this, the two mutually facing lens surfaces of lenses L210, L211 in this embodiment have a greater effect on the course

of the rays in comparison with the respective other lens surfaces of the corresponding lenses L210, L211.

With a length of 1,000 mm and a maximum lens diameter of 237.3 mm, this lens arrangement has a numerical aperture of 0.75 at a wavelength of 193.3 nm. The image field diagonal is 27.21 mm. A structure width of 0.15 μm is resolvable. The greatest deviation from the ideal wavefront is 13.0 mλ. The exact lens data with which these performance data were attained can be found in Table 2.

A further embodiment of a lens arrangement 19 for the wavelength 248.38 nm is shown in Fig. 4. This lens arrangement 19 has three lenses L305, L310, L328 which respectively have an aspheric lens surface 27, 29, 31. The aspheric lens surfaces 27, 29 have been left at the positions given by Fig. 3. The coma of middle order can be adjusted for the image field zone by means of the aspheric lens surface 27. The repercussions on sections in the tangential direction and in the sagittal direction are then small.

The additional, third aspheric lens surface 31 is arranged on the mask side on the lens L328. The aspheric lens surface 31 supports coma correction toward the image field edge.

By means of these three aspheric lens surfaces 27, 29, 31, there are attained, at a wavelength of 248.38 nm and at a length of only 1,000 mm and a maximum lens diameter of 247.2 mm, the further increased numerical aperture of 0.77 and a structure width of 0.14 μm which can be well resolved in the whole image field. The maximum deviation from the ideal wavefront is 12.0 mλ.

In order to keep the diameter of the lenses in LG5 small, and in order for a Petzval sum

which, advantageously for the system, should be kept nearly zero, the three lenses L312, L313, L314 in the third lens group LG3 are enlarged. The thicknesses, and thus the diameters, of other lenses, particularly the lenses of the first group LG1, have been reduced in order to furnish the required axial constructional space for these three lenses L312-L314. This is an excellent way to arrange very large image fields and apertures in a restricted constructional space.

The high image quality which is attained by this lens arrangement can be seen in Figs. 5a-5g, 6a-6g and 7a-7f.

Figs. 5a-5g give the meridional transverse aberration DYM for the image height Y′ (in mm). All show an outstanding course up to the highest DW′.

Figs. 6a-6g give the sagittal transverse aberrations DZS as a function of the half aperture angle DW′ for the same image heights (mm).

Figs. 7a-7f give the groove error DYS, which is nearly zero throughout.

The exact lens data can be found in Table 3; the aspheric lens surfaces 27, 29, 31 have a considerable participation in the high image quality which can be ensured.

A further lens arrangement for the wavelength $\lambda = 248.38$ nm is shown in Fig. 8. With a length of only 1,000 mm, this lens arrangement 19 has, with only three aspheric lens surfaces 27, 29, 31, a numerical aperture of 0.8; a structure width of 0.13 μm is well resolvable in the whole image field, whose diagonal is 27.21 mm. The maximum lens diameter is 255 mm and occurs in the region of the fifth lens group LG5. The lens diameter is unusually small for the numerical aperture of 0.8 at an image field having a 27.21 mm diagonal. All three aspheric lens surfaces 27, 29, 31 are in the front lens groups LG1-LG3 of the lens arrangement 19. The deviation from

the ideal wavefront is only 9.2 mλ in this lens arrangement.

The exact lens data of this lens arrangement can be found in Table 4.

A further increase of the numerical aperture, from 0.8 to 0.85, could be attained by the provision of a further, fourth aspheric 33 on the side of the lens L513 remote from the illuminating device. This high numerical aperture, from which there results an acceptance angle of 116.4°, as against an angle of 88.8° with a numerical aperture of 0.70, is unparalleled for the image field with diagonal 27.21 mm. The well resolvable structure width is 0.12 μm, and the maximum deviation from the ideal wavefront is only 7.0 mλ. Such a lens arrangement 19 is shown in Fig. 9, and the exact lens data can be found in Table 5.

In comparison with the preceding embodiments of Figs. 1-3 and with the cited DE 198 18 444 A, the last two lenses are united into one lens in this lens arrangement 19. By this measure, in addition to the savings in lens production, a lens mounting can be saved in the end region, so that constructional space is created for auxiliary devices, especially for a focus sensor.

A lens arrangement 19 designed for the wavelength $\lambda = 157.63$ nm is shown in Fig. 10. The image field which can be illuminated with this lens arrangement has been reduced to 6×13 mm, with an image field diagonal of 14.3 mm, and is adapted for the stitching process.

With a length of only 579.5 mm and a maximum diameter of 167 mm, and with four aspheric lens surfaces 27, 29, 31, 33, a numerical aperture of 0.85 and a well resolvable structure width of 0.07 μm were attained. The deviation from the ideal wavefront is 9.5 mλ at the wavelength $\lambda = 157.63$ nm.

The absorption of quartz lenses is quite high because of the short wavelength, so that

recourse was increasingly had to CaF_2 as the lens material. Single quartz glass lenses are provided in the region of the waists 23, 25, i.e., in the second and fourth lens groups LG2 and LG4. These quartz glass lenses are to have the highest possible transmission. A further lens of quartz glass, in the form of a meniscus lens L625, is provided in the lens group LG5 to form an achromat. Furthermore in lens group LG6, the lens L628 having an aspheric lens surface is of quartz glass. The aspheric surface 33 is thus constituted of the material which is easier to process.

The color longitudinal error of this lens arrangement 19 is thus very small, even at this very high numerical aperture.

The embodiments hereinabove show that good performance data can be attained without aspheric surfaces (27, 29, 31, 33) having large diameters, especially in the fifth lens group. The small aspheric lens surfaces utilized can easily be made and tested.

These lens arrangements 19 illustrated in the embodiments show solely the design space set out by the claims. Of course, the features according to the claims and their combinations, put in concrete terms with the aid of the embodiments, can be combined with each other.

Table 1
page 1

m709a

Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	17.2885		62.436
L101	-143.20731	6.0000	SIO2	62.972
	599.77254	7.6370	He	70.359
L102	-3269.25331	17.8056	SIO2	72.015
	-215.68976	.7500	He	74.027
L103	6352.48088	21.0301	SIO2	79.278
	-222.97760	.7500	He	80.492
L104	375.05253	22.1160	SIO2	83.813
	-496.09705	.7500	He	83.813
L105	191.46102	26.2629	SIO2	81.276
	-1207.32624	.7500	He	80.032
L106	180.94629	15.5881	SIO2	72.339
	100.48825	25.3787	He	62.801
L107	-3031.88082	6.0000	SIO2	62.147
	122.14071	23.8679	He	58.984
L108	-295.91467	9.3246	SIO2	59.196
	-187.69352	.7500	He	59.874
L109	-199.96963	6.0000	SIO2	59.882
	184.23629	33.9482	He	62.911
L110	-112.01095	6.0000	SIO2	64.128
	-684.63799 A	12.5079	He	75.868
L111	-225.51622	18.6069	SIO2	78.258
	-137.30628	.7500	He	81.928
L112	5312.93388	38.3345	SIO2	99.979
	-178.79712	.7500	He	101.920
L113	344.71979	39.8511	SIO2	111.294
	-397.29552	.7500	He	111.237
L114	165.51327	39.6778	CAF2	101.552
	7755.09540	.7500	He	99.535
L115	195.28524	23.8921	SIO2	87.267
	119.99272	32.2730	He	72.012
L116	-452.93918	6.0000	SIO2	70.763
	287.33119	20.7820	He	66.677
L117	-218.82578	6.0000	SIO2	66.150
	156.44429	40.5757	He	66.003
L118	-103.90786	6.4932	SIO2	66.694
	5916.68891	13.3336	He	80.536
L119	-344.93456	19.8584	CAF2	82.790
	-165.11801	.7500	He	86.174
L120	-11871.72431	38.5095	CAF2	100.670
	-174.34079	.7500	He	102.666
L121	586.98079	31.6915	CAF2	111.739
	-414.20537	.7500	He	112.097
	infinity	3.6849	He	111.399
	stop	.0000	He	111.399
	infinity	1.2566	He	111.830
L122	284.64742	45.7670	CAF2	114.801
	-414.78783	17.9539	He	114.410
L123	-234.72451	14.5097	SIO2	113.062

Table 1

page 2

	-593.08647	14.7730	He	114.454
L124	-323.13567	42.1874	SIO2	114.235
	-229.06128	.7500	He	117.505
L125	180.27184	31.4105	SIO2	105.659
	652.02194	.7500	He	103.698
L126	143.20049	28.2444	SIO2	91.476
	383.51531	14.7177	He	88.206
L127	-2122.47818	14.1140	SIO2	85.843
	312.60012	1.3119	He	74.816
L128	111.92162	46.5147	SIO2	66.708
	53.69539	2.2604	He	40.084
L129	51.14657	27.3776	CAF2	39.074
	492.53747	3.7815	He	32.621
	infinity	3.0000	SIO2	29.508
	infinity	12.0000		27.848
	infinity			14.021

Aspheric Constants:

Coefficients of the aspheric surface n:
[where n is 21]

EX = 0.0000

C1 = 0,61839643 $\cdot 10^{-8}$

C 2 = - 0,11347761 $\cdot 10^{-11}$

C 3 = 0,32783915 $\cdot 10^{-15}$

C 4 = -0,22000186 $\cdot 10^{-20}$

Table 2
page 1

m736a

Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	16.6148		60.752
L201	-140.92104	7.0000	SIO2	61.267
	-4944.48962	4.5190		67.230
L202	-985.90856	16.4036	SIO2	68.409
	-191.79393	.7500		70.127
L203	18376.81346	16.5880	SIO2	73.993
	-262.28779	.7500		74.959
L204	417.82018	21.1310	SIO2	77.129
	-356.76055	.7500		77.193
L205	185.38468	23.3034	SIO2	74.782
	-1198.61550 A	.7500		73.634
L206	192.13950	11.8744	SIO2	68.213
	101.15610	27.6353		61.022
L207	-404.17514	7.0000	SIO2	60.533
	129.70591	24.1893		58.732
L208	-235.98146	7.0584	SIO2	59.144
	-203.88450	.7500		60.201
L209	-241.72595	7.0000	SIO2	60.490
	196.25453	33.3115		65.017
L210	-122.14995	7.0000	SIO2	66.412
	-454.65265 A	10.8840		77.783
L211	-263.01247	22.6024	SIO2	81.685
	-149.71102	1.6818		86.708
L212	-23862.31899	43.2680	SIO2	104.023
	-166.87798	.7500		106.012
L213	340.37670	44.9408	SIO2	115.503
	-355.50943	.7500		115.398
L214	160.11879	41.8646	SIO2	102.982
	4450.50491	.7500		100.763
L215	172.51429	14.8251	SIO2	85.869
	116.88490	35.9100		74.187
L216	-395.46894	7.0000	SIO2	72.771
	178.01469	28.0010		66.083
L217	-176.03301	7.0000	SIO2	65.613
	188.41213	36.7224		66.293
L218	-112.43820	7.0059	SIO2	66.917
	683.42330	17.1440		80.240
L219	-350.01763	19.1569	SIO2	82.329
	-194.58551	.7514		87.159
L220	-8249.50149	35.3656	SIO2	99.995
	-213.88820	.7500		103.494
L221	657.56358	31.3375	SIO2	114.555
	-428.74102	.0000		115.245
	infinity	2.8420		116.016
	stop	.0000		116.016
L222	820.30582	27.7457	SIO2	118.196
	-520.84842	18.4284		118.605
L223	330.19065	37.7588	SIO2	118.273
	-672.92481	23.8692		117.550

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Table 2
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L224	-233.67936	10.0000	SIO2	116.625
	-538.42627	10.4141		117.109
L225	-340.26626	21.8583	SIO2	116.879
	-224.85666	.7500		117.492
L226	146.87143	34.5675	SIO2	100.303
	436.70958	.7500		97.843
L227	135.52861	29.8244	SIO2	86.066
	284.57463	18.9234		79.427
L228	-7197.04545	11.8089	SIO2	72.964
	268.01973	.7500		63.351
L229	100.56453	27.8623	SIO2	56.628
	43.02551	2.0994		36.612
L230	42.30652	30.9541	SIO2	36.023
	262.65551	1.9528		28.009
	infinity	12.0000		27.482
	infinity			13.602

Aspheric Constants:

Coefficients of the aspheric surface n:
[where n is 29]

EX = -0,17337407 $\cdot 10^{3}$
C 1 = 0,15292522 $\cdot 10^{-7}$
C 2 = 0,18756271 $\cdot 10^{-11}$
C 3 = -0,40702661 $\cdot 10^{-15}$
C 4 = 0,26176919 $\cdot 10^{-19}$
C 5 = -0,36300252 $\cdot 10^{-23}$
C 6 = 0,42405765 $\cdot 10^{-27}$

Coefficients of the aspheric surface n:
[where n is 27]

EX = -0.36949981 $\cdot 10^{1}$
C 1 = 0,20355563 $\cdot 10^{-7}$
C 2 = -0,22884234 $\cdot 10^{-11}$
C 3 = -0,23852814 $\cdot 10^{-15}$
C 4 = -0,19091022 $\cdot 10^{-19}$
C 5 = 0,27737562 $\cdot 10^{-23}$
C 6 = -0,29709625 $\cdot 10^{-27}$

Table 3
page 1

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Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	17.8520		60.958
L301	-131.57692	7.0000	SIO2	61.490
	-195.66940	.7500		64.933
L302	-254.66366	8.4334	SIO2	65.844
	-201.64480	.7500		67.386
L303	-775.65764	14.0058	SIO2	69.629
	-220.44596	.7500		70.678
L304	569.58638	18.8956	SIO2	72.689
	-308.25184	.7500		72.876
L305	202.68033	20.7802	SIO2	71.232
	-1120.20883	A7500		70.282
L306	203.03395	12.1137	SIO2	65.974
	102.61512	26.3989		59.566
L307	-372.05336	7.0000	SIO2	59.203
	144.40889	23.3866		58.326
L308	-207.93626	7.0303	SIO2	58.790
	-184.65938	.7500		59.985
L309	-201.97720	7.0000	SIO2	60.229
	214.57715	33.1495		65.721
L310	-121.80702	7.0411	SIO2	67.235
	-398.26353 A	9.7571		79.043
L311	-242.40314	22.4966	SIO2	81.995
	-146.75339	.7553		87.362
L312	-2729.19964	45.3237	SIO2	104.995
	-158.37001	.7762		107.211
L313	356.37642	52.1448	SIO2	118.570
	-341.95165	1.1921		118.519
L314	159.83842	44.6278	SIO2	105.627
	2234.73586	.7698		102.722
L315	172.14697	16.8360	SIO2	88.037
	119.53455	36.6804		75.665
L316	-392.52196	7.0000	SIO2	74.246
	171.18767	29.4986		67.272
L317	-176.75022	7.0000	SIO2	66.843
	186.50720	38.4360		67.938
L318	-113.94008	7.0213	SIO2	68.650
	893.30270	17.7406		82.870
L319	-327.77804	18.9809	SIO2	85.090
	-192.72640	.7513		89.918
L320	-3571.89972	34.3608	SIO2	103.882
	-209.35555	.7500		106.573
L321	676.38083	32.6220	SIO2	119.191
	-449.16650	.0000		119.960
	infinity	2.8420		120.991
	stop	.0000		120.991
L322	771.53843	30.6490	SIO2	123.568
	-525.59771	13.4504		124.005
L323	330.53202	40.0766	SIO2	123.477
	-712.47666	23.6787		122.707

L324	-250.00950	10.0000	SIO2	121.877
	-813.10270	14.8392		121.995
L325	-344.63359	20.3738	SIO2	121.081
	-239.53067	.7500		121.530
L326	148.13385	34.7977	SIO2	102.544
	399.32557	.7510		99.992
L327	132.97289	29.7786	SIO2	87.699
	294.53397	18.8869		82.024
L328	-3521.27938 A	11.4951	SIO2	75.848
	287.11066	.7814		65.798
L329	103.24804	27.8602	SIO2	58.287
	41.64286	1.9089		36.734
L330	41.28081	31.0202	SIO2	36.281
	279.03201	1.9528		28.934
	infinity	12.0000		28.382
	infinity			13.603

Aspheric Constants:

Coefficients of the aspheric surface n: [where n is 29]

EX = -0,16784093 $\cdot 10^{3}$
C 1 = 0,49600479 $\cdot 10^{-9}$
C 2 = 0,31354487 $\cdot 10^{-11}$
C 3 = -0,55827200 $\cdot 10^{-16}$
C 4 = 0,44673095 $\cdot 10^{-19}$
C 5 = -0,73057048 $\cdot 10^{-23}$
C 6 = 0,91524489 $\cdot 10^{-27}$

Coefficients of the aspheric surface n: [where n is 27]

EX = -0,22247325 $\cdot 10^{1}$
C 1 = 0,24479895 $\cdot 10^{-7}$
C 2 = -0,22713172 $\cdot 10^{-11}$
C 3 = 0,36324126 $\cdot 10^{-15}$
C 4 = -0,17823969 $\cdot 10^{-19}$
C 5 = 0,26799048 $\cdot 10^{-23}$
C 6 = -0,27403392 $\cdot 10^{-27}$

Coefficients of the aspheric surface n: [where n is 31]

EX = 0
C 1 = -0,45136584 $\cdot 10^{-09}$
C 2 = 0,34745936 $\cdot 10^{-12}$
C 3 = 0,11805250 $\cdot 10^{-17}$
C 4 = -0,87762405 $\cdot 10^{-21}$

Table 4
page 1

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Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	11.4557		61.339
L401	-273.19568	7.0000	SIO2	62.263
	-277.09708	.7000		63.765
L402	-861.38886	8.9922	SIO2	64.989
	-339.26281	.7000		65.826
L403	118124.13719	11.2867	SIO2	66.916
	-365.70154	.7000		67.416
L404	685.10936	13.1651	SIO2	67.995
	-485.98278	.7000		68.012
L405	387.56973	17.2335	SIO2	67.247
	-473.09537 A	.7000		66.728
L406	268.03965	9.9216	SIO2	62.508
	149.12863	23.8122		58.531
L407	-184.82383	7.0000	SIO2	58.029
	176.30719	21.4194		57.646
L408	-186.59114	7.0000	SIO2	58.045
	218.73570	29.5024		63.566
L409	-129.31068	7.0000	SIO2	65.030
	-531.44773 A	17.2306		76.481
L410	-307.52016	22.4527	SIO2	85.643
	-148.36184	.7000		88.946
L411	-1302.18676	41.0516	SIO2	105.065
	-162.48723	.7000		107.106
L412	621.16978	41.1387	SIO2	118.007
	-294.49119	.7000		118.347
L413	160.06951	49.7378	SIO2	109.803
	-2770.71439 A	.7000		107.961
L414	152.16529	16.7403	SIO2	89.160
	106.43165	39.9369		76.189
L415	-530.55958	7.0000	SIO2	74.955
	170.63853	31.4993		68.381
L416	-164.61084	7.0000	SIO2	67.993
	262.65931	36.2904		69.679
L417	-113.57141	8.4328	SIO2	70.272
	772.56149	21.7682		85.377
L418	-278.33295	16.4890	SIO2	87.710
	-198.24799	.8689		92.554
L419	-3464.64038	37.5900	SIO2	107.590
	-214.63481	1.1929		111.045
L420	2970.07848	32.3261	SIO2	122.434
	-350.93217	2.5303		123.849
L421	1499.34256	25.8265	SIO2	127.128
	-561.19644	.0000		127.371
	infinity	.7510		126.559
	stop	.0000		126.559
L422	821.09016	39.5191	SIO2	127.453
	-1995.20557	.7000		127.499
L423	337.02437	41.8147	SIO2	126.619
	-559.23025	25.0233		125.851

Table 4
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L424	-242.66564	7.0000	SIO2	124.960
	-891.19390	9.7905		125.057
L425	-492.17516	41.0678	SIO2	124.887
	-242.55195	.7000		125.845
L426	145.04614	37.2406	SIO2	104.033
	406.88892	.7008		101.079
L427	119.31280	31.5532	SIO2	85.742
	249.69473	15.2917		79.561
L428	1411.93157	7.8700	SIO2	74.994
	281.90273	.7011		66.830
L429	143.95136	55.0835	SIO2	61.517
	404.13980	15.0000		32.177
	infinity	.0001		13.603
	infinity			13.603

Aspheric Constants:

Coefficients of the aspheric surface n:
[where n is 27]

EX = 0,45321787 $\cdot 10^{2}$
C 1 = 0,12027601 $\cdot 10^{-7}$
C 2 = -0,16206398 $\cdot 10^{-11}$
C 3 = -0,41686011 $\cdot 10^{-15}$
C 4 = 0,38440137 $\cdot 10^{-19}$
C 5 = -0,15095918 $\cdot 10^{-23}$
C 6 = -0,84812561 $\cdot 10^{-28}$

Coefficients of the aspheric surface n:
[where n is 29]

EX = 0
C 1 = -0,97452539 $\cdot 10^{-7}$
C 2 = 0,32591079 $\cdot 10^{-11}$
C 3 = 0,97426255 $\cdot 10^{-16}$
C 4 = -0,846124 $\cdot 10^{-20}$
C 5 = -0,12332031 $\cdot 10^{-23}$
C 6 = 0,14443713 $\cdot 10^{-27}$

Coefficients of the aspheric surface n:
[where n is 33]

EX = 0
C 1 = 0,63144137 $\cdot 10^{-8}$
C 2 = 0,21837618 $\cdot 10^{-12}$
C 3 = 0,22801998 $\cdot 10^{-18}$
C 4 = -0,87807963 $\cdot 10^{-21}$
C 5 = 0,42592446 $\cdot 10^{-25}$
C 6 = -0,85709164 $\cdot 10^{-30}$

Table 5
page 1

j430a

Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	9.9853		61.649
L501	-265.92659	6.0000	SIO2	62.237
	857.92226	5.9813		65.916
L502	-2654.69270	14.4343	SIO2	66.990
	-244.65690	.7500		68.482
L503	1036.40194	15.9955	SIO2	71.883
	-333.95446	.7500		72.880
L504	359.47552	18.5128	SIO2	74.430
	-532.67816	.7500		74.416
L505	213.38035	21.4562	SIO2	72.985
	-1441.22634 A	.7500		72.045
L506	261.90156	6.5306	SIO2	67.809
	115.92184	28.4856		62.818
L507	-267.21040	6.0000	SIO2	62.411
	175.09702	23.2443		61.923
L508	-213.08557	6.0000	SIO2	62.365
	199.61141	30.8791		68.251
L509	-158.73046	6.0337	SIO2	69.962
	-1108.92217 A	10.9048		81.119
L510	-314.37706	20.6413	SIO2	84.163
	-169.59197	.8014		88.902
L511	-3239.97175	43.6396	SIO2	106.289
	-166.44726	.7500		108.724
L512	495.41910	48.8975	SIO2	123.274
	-288.85737	.7500		123.687
L513	153.24868	48.7613	SIO2	113.393
	920.32139 A	.7500		111.134
L514	163.02602	15.7110	SIO2	96.188
	124.97610	44.2664		84.961
L515	-422.99493	6.0000	SIO2	83.633
	184.60620	31.4986		76.498
L516	-241.93022	6.0000	SIO2	76.180
	158.30899	51.3978		77.396
L517	-117.43130	6.5332	SIO2	78.345
	2476.47953	21.4666		98.469
L518	-311.36041	15.2223	SIO2	101.209
	-221.58556	.7500		105.324
L519	-934.37047	37.6761	SIO2	122.239
	-216.75809	.7500		125.425
L520	3623.94786	39.6266	SIO2	146.583
	-370.69232	1.1289		148.219
L521	1209.82944	39.1543	SIO2	157.194
	-613.71745	.0000		157.954
	infinity	.7500		158.061
	stop	.0000		158.061
L522	709.88915	36.2662	SIO2	160.170
	-1035.75796	.7500		160.137
L523	313.44889	58.8000	SIO2	155.263
	-1046.56219	28.7484		153.730

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L524	-328.67790	15.0000	SIO2	152.447
	-1283.32936	14.7084		148.826
L525	-540.24577	23.9839	SIO2	148.336
	-305.19883	.7510		146.189
L526	152.28321	42.3546	SIO2	114.055
	384.50964	.7531		109.924
L527	124.66784	31.8554	SIO2	91.106
	279.60513	16.6796		86.038
L528	-28987.53974	7.4387	SIO2	82.126
	316.02224	.8631		72.044
L529	180.51161	54.1269	SIO2	67.036
	1341.25511	15.0000		37.374
	infinity	.0001		13.604
	infinity			13.604

Aspheric Constants:

Coefficients of the aspheric surface n: [where n is 29]

EX = -0,27012883 $\cdot 10^{3}$
C 1 = -0,48014089 $\cdot 10^{-7}$
C 2 = 0,30075830 $\cdot 10^{-11}$
C 3 = 0,34922943 $\cdot 10^{-16}$
C 4 = 0,26946301 $\cdot 10^{-19}$
C 5 = -0,58250631 $\cdot 10^{-23}$
C 6 = 0,68991391 $\cdot 10^{-27}$

Coefficients of the aspheric surface n [where n is 27]

EX = 0,41249481 $\cdot 10^{1}$
C 1 = -0,38239182 $\cdot 10^{-8}$
C 2 = -0,14976009 $\cdot 10^{-11}$
C 3 = -0,25208193 $\cdot 10^{-16}$
C 4 = -0,76282128 $\cdot 10^{-20}$
C 5 = 0,13017800 $\cdot 10^{-23}$
C 6 = -0,14206614 $\cdot 10^{-27}$

Coefficients of the aspheric surface n: [where n is 33]

EX = 0,26320110 $\cdot 10^{1}$
C 1 = 0,27448935 $\cdot 10^{-8}$
C 2 = -0,18100074 $\cdot 10^{-12}$
C 3 = 0,58696756 $\cdot 10^{-17}$
C 4 = -0,58955753 $\cdot 10^{-21}$
C 5 = 0,16526308 $\cdot 10^{-25}$
C 6 = -0,25708759 $\cdot 10^{-30}$

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Table 5
page 3

Coefficients of the aspheric surface n : [where n is 31]

$EX = -0{,}96865859 \cdot 10^{5}$
$C\,1 = -0{,}42411179 \cdot 10^{-8}$
$C\,2 = 0{,}12306068 \cdot 10^{-12}$
$C\,3 = 0{,}69229786 \cdot 10^{-17}$
$C\,4 = 0{,}80135737 \cdot 10^{-20}$
$C\,5 = -0{,}14022540 \cdot 10^{-23}$
$C\,6 = 0{,}79827308 \cdot 10^{-28}$

Table 6
page 1

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Lenses	Radii	Thicknesses	Glasses	½ x Lens Diameter
	infinity	5.9005	N2	32.429
L601	-125.95821	3.6410	CAF2	32.780
	243.24465	5.2309	He	35.323
L602	2472.77263	9.2265	CAF2	36.826
	-132.46523	.3958	He	37.854
L603	544.60759	8.6087	CAF2	40.080
	-188.98512	.6007	He	40.516
L604	180.26444	10.3984	CAF2	41.764
	-394.70139	.4244	He	41.743
L605	101.06312	12.8236	CAF2	40.955
	-691.58627 A	.5111	He	40.455
L606	135.75849	3.1245	CAF2	37.553
	57.03094	16.2396	He	34.284
L607	-268.26919	5.9149	CAF2	33.871
	116.53669	10.9654	He	33.188
L608	-142.54676	3.2195	SIO2	33.372
	100.09171	16.1921	He	35.360
L609	-83.03185	3.2311	SIO2	36.264
	-453.73264 A	5.1711	He	41.718
L610	-167.92924	12.0560	CAF2	43.453
	-93.29791	.4204	He	47.010
L611	-1270.46545	24.2891	CAF2	56.224
	-90.89540	1.1471	He	58.224
L612	266.81271	25.6379	CAF2	66.498
	-171.23687	.3519	He	66.755
L613	82.41217	26.8409	CAF2	61.351
	529.17259 A	.5132	He	60.098
L614	81.87977	8.2278	CAF2	50.462
	64.06536	22.9801	He	44.346
L615	-259.83061	3.3437	SIO2	43.473
	124.29419	13.5357	He	40.266
L616	-197.29109	3.0000	SIO2	39.809
	67.83707	24.5613	He	39.571
L617	-64.97274	4.6170	SIO2	40.050
	1947.71288	9.3909	He	49.830
L618	-182.16003	7.8052	CAF2	51.480
	-118.82950	.3753	He	53.449
L619	-633.93522	19.7976	CAF2	63.119
	-115.14087	.3706	He	64.793
L620	2647.04517	19.8039	CAF2	75.458
	-197.41705	2.7167	He	76.413
L621	668.45083	30.1057	CAF2	81.369
	-322.45899	.0001	He	82.659
	infinity	.3948	He	82.583
	stop	.0000		82.583
L622	395.84774	16.8734	CAF2	83.488
	-535.79877	.3500	He	83.449
L623	185.28880	28.1341	CAF2	80.761
	-598.21798	15.6657	He	80.133

Table 6
page 2

L624	-175.54365	7.9803	SIO2	79.485
	-571.27581	9.7972	He	78.592
L625	-265.73712	11.6714	CAF2	78.015
	-156.05301	.3500	He	78.036
L626	79.45912	22.6348	CAF2	60.151
	199.26460	.3500	He	57.925
L627	67.01872	15.8836	CAF2	48.063
	140.01631	8.6050	He	45.305
L628	2265.71693 A	4.0939	SIO2	43.177
	167.06050	2.0915	He	38.352
L629	102.24013	24.5664	CAF2	34.878
	662.00756	9.4740	N2	22.044
	UNENDL	.0001	N2	7.166
	UNENDL			7.166

Aspheric Constants:

Coefficients of the aspheric surface n: [where n is 29]

EX= $-0,7980946 \cdot 10^{2}$
C 1 = $-0,21353640 \cdot 10^{-6}$
C 2 = $0,56257 \cdot 10^{10}$
C 3 = $-0,39122939 \cdot 10^{-14}$
C 4 = $-0,24089766 \cdot 10^{-18}$
C 5 = $0,30258982 \cdot 10^{-22}$
C 6 = $0,1437923 \cdot 10^{-25}$

Coefficients of the aspheric surface n: [where n is 27]

EX = $0,1660595 \cdot 10^{1}$
C 1 = $-0,12449719 \cdot 10^{-7}$
C 2 = $-0,39565 \cdot 10^{-10}$
C 3 = $-0,10241741 \cdot 10^{-14}$
C 4 = $-0,19631485 \cdot 10^{-17}$
C 5 = $0,11604236 \cdot 10^{-20}$
C 6 = $-0,4669584 \cdot 10^{-24}$

Coefficients of the aspheric surface n: [where n is 33]

EX = $0,1614147 \cdot 10^{0}$
C 1 = $0,14130608 \cdot 10^{-7}$
C 2 = $-0,9747553 \cdot 10^{-11}$
C 3 = $0,20478684 \cdot 10^{-15}$
C 4 = $-0,17732262 \cdot 10^{-18}$
C 5 = $0,29715991 \cdot 10^{-22}$
C 6 = $-0,19032581 \cdot 10^{-26}$

21-M

Table 6
page 3

Coefficients of the aspheric surface n:
[where n is 31]

EX = 0
C 1 = $-0{,}18139679 \cdot 10^{-7}$
C 2 = $0{,}26109069 \cdot 10^{-11}$
C 3 = $0{,}23340548 \cdot 10^{-14}$
C 4 = $0{,}29943791 \cdot 10^{-17}$
C 5 = $-0{,}13596787 \cdot 10^{-20}$
C 6 = $0{,}21788235 \cdot 10^{-24}$

21-N

Abstract of the Disclosure

The invention relates to a projection lens comprising a lens assembly that has at least one first narrowing of the group of light beams. A lens with a non-spherical surface is located in front of and/or behind the first narrowing.